IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Sirignano et al
Appl. No.	:	10/766,132
Filing Date	:	January 27, 2004
Title	:	Miniature, Liquid-Fuel Combustion Chamber
Group Art Unit	:	3749
Examiner	:	Sara Sachie Clarke
Docket No.	:	703538.4032

RULE 132 DECLARATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

1. I, Carlos Fernandez-Pello, am a Professor of Mechanical Engineering at the University of California, Berkeley. My Curriculum Vitae and a representative list of publications are attached as Exhibit 1.

2. I have no financial interest in the above-referenced patent application ("the application").

3. I am personally acquainted with Professors William A. Sirignano and Derek Dunn-Rankin at the University of California Irvine. Professors Sirignano and Dunn-Rankin are the inventors/applicants listed in the application.

4. I have reviewed the application as filed on January 27, 2004. The subject matter of the application is directed generally to the field of combustors and specifically to miniature combustors on a sub-centimeter scale. I am of the opinion that one of ordinary skill in the art would possess an MS or PhD degree in such fields of study as mechanical engineering, aerospace engineering, chemical engineering, chemistry, and physics.

5. I am of the opinion that the application describes and teaches to one of ordinary skill in the art a novel sub-centimeter sized combustor chamber and method of operation. The currently pending claims are directed, as claimed in claim 1, to a miniature combustor comprising a "chamber having a lateral dimension transverse to a major flow direction within the chamber that is sub-centimeter" and, in dependent claim 2, "the lateral dimension is in a range of about 1.0 to 3.0 millimeters." The claims, as claimed in claim 15, are also directed to a combustion process in a combustion chamber which "has a lateral dimension transverse to a major flow direction within the chamber that is sub-centimeter." The dimensional aspects of the claimed miniature combustion chambers create a different operational phenomena, that prevents the principles of larger combustion chamber systems from operating in smaller, miniaturized combustion chambers. The different operational phenomena is due to an enhancement of the heat losses from the combustion reaction to the walls of the miniaturized combustor that inhibits the combustion of the fuel in these combustors unless specific thermal management systems are implemented.

6. At the claimed dimensions, i.e., sub-centimeter lateral dimension, which are comparable to known quenching distances, the surface-to-volume ratio for the combustion chamber is so large that a flame is typically not sustainable within the chamber due to the large heat transfer losses to the chamber walls. To overcome this wall quenching phenomenon, the applicants teach

and claim injecting a liquid, fuel or inert, as a film that covers the entire or substantially the entire area of the chamber walls. With a liquid film applied to and maintained on the chamber walls, the heat transferred from hot combustion gases is captured by the liquid film causing the liquid to evaporate and in turn keeping the liquid at its vaporization temperature, which for most fuels is much lower than the combustion temperature. The low liquid temperature protects the chamber walls form the combustion temperature and prevents substantial heat loss to the chamber walls. In addition, when the liquid is a fuel, the heat transferred from the hot combustion gases will serve to aid in vaporization of the liquid fuel so it is burned before it exits the chamber.

7. Current technology for larger systems does not rely on liquid fuel filming on the chamber walls (though some fuel is intentionally vaporized from intake manifolds in IC engines as part of the charge preparation). Instead, to keep the ratio of liquid surface area to liquid volume large enough to sustain high fuel vaporization rates, the fuel is typically injected as a spray. The intention is to vaporize the liquid as a spray before very much liquid deposits on the walls or solid surfaces of the chamber. If the fuel were filmed in these larger engines or combustors, the surface area of the liquid would not be large enough to sustain the needed vaporization rate for combustion. Because the S/V ratio of any wall film will grow as the volume of the combustor decreases, the liquid fuel film in combustors in the sub-centimeter size range tends to provide a liquid surface area for vaporization comparable to a vaporizing spray. Furthermore, the liquid fuel film protects against heat losses at the wall and, thus, quenching, that a vaporizing spray does not. Simply scaling existing combustion systems down to the lateral dimensions taught and claimed would result in increased heat loss and subsequent combustion failure due to quenching. Some sprayed droplets might impact the combustor walls but, without filming on the entire or substantially the entire

chamber wall, heat protection of all parts of the wall would not occur. Impacting droplets might only lead to less complete and thereby less efficient combustion.

8. I am of the opinion that it would not be obvious to one of ordinary skill in the art at the time of the applicant's invention to have scaled the apparatuses of Schirmer (1959), Meurer, Schirmer (1986) and Rao to applicant's dimensions. For combustion chambers, dimensions cannot simply scale in proportion because wall effects on the fuel combustion process become increasingly important as the size of the combustor is reduced. Physics and chemical processes which these authors never discuss and, in fact, clearly ignore become important. Thus, the teaches of these references would not lead one of ordinary skill in the art to the miniature combustion chamber and process taught and claimed by the applicants.

9. Schirmer (1959) does not mention the importance of heat loss and quenching. It is clear that he has not considered the scaling effects resulting in quenching since he prescribes the addition of air to quench the flame in the chamber thereby implying the non-existence of an important wall-quenching effect. Schirmer (1959) indicates that there is substantial heat transfer to the chamber wall at column 3, lines 30—32 by noting that the chamber must have high mechanical strength and resistance to elevated temperatures. In the claimed miniature combustion chamber the liquid film will keep the wall temperature low thus it is not necessary to have a chamber with high resistance to elevated temperatures.

10. It is also clear that Schirmer (1959) is directed to larger-scale combustors than those taught and claimed by the applicants. For instance, at column 2, lines 18—20 Schirmer (1959) indicates the presence of a "highly turbulent shear interface of the fuel and the air." It is common textbook knowledge that turbulence occurs when the Reynolds number, which increases in direct

proportion to the length scale of the flow passage, is large, or the onset of turbulence in a fluid occurs only when the product of the velocity and the representative length dimension exceed a threshold. Another indication that Schirmer (1959) is directed to larger-scale combustors occurs at column 2, Lines 22—25, where velocities up to 250 feet per second are deemed allowable. In a chamber dimension of ten centimeters or less, this allows about a millisecond or less for combustion to occur, which is usually too short a time to accomplish the vaporization, mixing of fuel vapor and oxidizer, and chemical oxidation processes which in totality and in sequence form the combustion process. Thus, Schirmer (1959) clearly relates only to the physics that operate in devices on a scale much larger than those taught and claimed by the applicants.

11. The statement at column 3, Lines 1-14 of Schirmer (1959) regarding "self-regulation of the wall temperature" is not correct. That is, self-regulation occurs as applicants indicate by maintaining a stable liquid film on the wall. Schirmer (1959) does not teach maintaining a stable liquid film on the wall. To the contrary, Schirmer (1959) states at column 2, lines 11—22:

> Broadly speaking, my combustion apparatus permits the introduction of fuel uniformly onto the entire inner surface of the primary combustion chamber through a porous liner spaced from the inner wall of the chamber, and the introduction of air in the form of a vortex into the primary combustion chamber so that the flow of air spirals or swirls coaxially through the primary combustion chamber. Combustion apparently is effected at the highly turbulent shear interface of the fuel and the air. The shear interface, and therefore the combustion occurs near the surface of the porous wall and in the mixing zone.

It is common text book knowledge that at the prescribed flow rates of Schirmer (1959), the shear forces would be such that the layer of fuel on the chamber walls will become unstable and break-up into droplets for vaporization and, thus, heat protection of chamber walls is lost.

12. Meurer also does not address the issues of heat loss and quenching associated with smaller dimensions. Specifically, Meurer does not prescribe that the combustion chamber wall

should be fully covered by the liquid to reduce heat losses. Moreover, Meurer teaches cooling the combustion wall with air, thus indicating an acceptance of heat loss to the walls. Scaling of Meurer would result in combustion failure due to quenching as a result.

13. Schirmer (1976) addresses gaseous fuel and atomized liquid fuel only. As discussed above, simply scaling of Schirmer's device to the dimensions of applicants, and nothing more, would result in combustion failure due to quenching.

14. Rao considers a situation in his vortex device where the liquid is not the fuel or a chemical reactant. Only heat transfer and no mass transfer occur between the liquid and the core gas flow. The class of devices discussed in Rao certainly does not include combustors.

15. Because internal combustion has the potential to simultaneously provide high power density and high energy density, which is desirable of power sources for devices requiring personal power such as cellular telephones, PDAs, laptop computers, etc., many researchers have attempted to explore it as a method for power generation on a miniature scale. Examples of such exploration include, a micro-gas turbine with a combustor volume of 0.04 cubic centimeters (see, Waitz et al., 120 Jnl. Fluids Engr., 109-117 (1998)), a mini (0.078 cc displacement) and a micro (0.0017 cc displacement) rotary engine (see Fu et al., 99F023 Combustion Inst., Western States Sect., Fall Mtg. (1999)), a microrocket with a 0.1 cubic centimeter combustion chamber (see Lindsay et al., IEEE Cat. No. 01CH37090, 606-610 (2001)), and a micro Swiss roll burner (see Sitzki et al., 3rd A-P Conf. Combustion (2001)). Although these devices have demonstrated the plausibility of internal combustion as a personal power source, they are not able to perform at efficiencies that make them competitive with the best available batteries. Thus, there is still a long felt, unsatisfied need for a

miniature power source with high power and energy density like the miniature combustor of the claimed invention.

I certify under penalty of perjury that the information submitted in this declaration is all true and correct.

Respectfully Submitted,

Dated: March 2, 2005 By: Carlos F-Pelli

RESUME-CARLOS FERNANDEZ-PELLO

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SUMMARY

Mechanical/Aeronautical Engineer specializing in combustion, heat and mass transfer, and thermodynamics. Microgravity combustion. Micro-scale power generation using combustion. Ignition and flame propagation in solid and liquid fuels. Smoldering and transition to flaming of porous materials. Meso and micro engines and combustors. Droplet combustion. Explosive burning of droplets and boiling of liquid fuel pools. Self-heating and ignition of combustible materials.

ACADEMIC BACKGROUND

Ph.D.	Engineering Science, University of California, San Diego, California, 1975
M.S.	Engineering Science, University of California, San Diego, California, 1973
Dr. Eng.	Aeronautical Engineering, Polytechnic University, Madrid, Spain, 1979
Aero. Eng.	Aeronautical Engineering, Polytechnic University, Madrid, Spain, 1968

PROFESSIONAL BACKGROUND

Education and Research (since receiving Ph.D.)

1980-present	Department of Mechanical Engineering, University of California, Berkeley, California. Professor (1986-present), Associate Dean Graduate Division U.C. Berkeley (2003-present). Vice-Chairman Graduate Council U.C. Berkeley (2000-2001). Vice-Chairman of Graduate Matters, ME Department (1997-2000), Associate Professor (1982-1986), Assistant Professor (1980-1982).
1983-present	Associate Faculty Scientist, Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, California
1980-1980	Associate Professor, Department of Mechanical Engineering, Northwestern University, Evanston, Illinois
1977-1980	Research Staff Member, Department of Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey.
1975-1976	Post-doctoral Research Fellow, Division of Engineering and Applied Physics, Harvard University, Cambridge, Massachusetts

Engineering Practice

1978-present	Consultant to government, industry and private sector. Work related to performance of combustion systems, accidental fires and explosions in industry and transportation. Testing of materials thermal and fire properties.
1968-1972	Research Engineer, SENER, Madrid, Spain. Development of heat exchangers and cooling towers.

PROFESSIONAL ACTIVITIES AND SERVICE

Member/Consultant/Reviewer: Royal Academy of Engineering of Spain, Member. American Society of Mechanical Engineering (ASME) Fellow. Universities Space Research Association, Microgravity Science and Applications Council (2001-present). Center for Pure and Applied Mathematics, U.C. Berkeley, board of directors (2001-2002). NASA Space Station Science and Applications Advisory Committee, (1990-1996). Lawrence Livermore National Laboratories, (1984-1997). National Institute of Standard and Technology, Center for Fire Research, (1982-83). CI, DOE, IAFSS, NASA, NFPA, NRC, NSF.

Editorial Advisory Board: Combustion Science and Technology (1992-present), Progress in Energy and Combustion Science (1995-present), Combustion and Flame (1994-2001).

Association Membership: The Combustion Institute, ASME (Fellow), AIAA, IAFSS, NFPA

FELLOWSHIPS AND AWARDS

The Philip Thomas Medal of Excellence for the Best Paper at the 6th International Symposium of Fire Safety Science. .Pi Tau Sigma Award for Excellence in Teaching, Department of Mechanical Engineering, U. C. Berkeley. Fellowships from the Fulbright and Juan March Foundations, the Japan Society for the Promotion of Science (JSPS) and Ministry for Industry and Technology (MITI), and the French and the Italian Centers for National Research.

RESEARCH ACTIVITIES (career long)

CURRENT PROJECTS

Smoldering and Transition to Flaming in Microgravity (NASA Space Flight Program): The objective of the project is to predict smoldering and the transition to flaming of foams, composite and cellulose materials in conditions expected in space based facilities. It includes experiments in normal gravity and in microgravity. The later are being conducted in the Space Shuttle, and are to be continued in the International Space Station. To date three space flight experiments have been conducted in the Space Shuttle, and five more are scheduled The results of the study are used to predict and prevent the potential onset of smoldering generated fires in ground and space based facilities.

Materials Flammability in Microgravity (NASA Space Flight Program): The project short term objective is to study the effect of low gravity on the flammability diagrams of combustible materials used in spacecraft's (plastics, cable jackets, electronic boards, etc.), and the fire properties derived from them. The final objective is the development of a new test that

describes conditions expected in space facilities (microgravity, low velocity variable oxygen concentration flow) for determining the fire properties of materials to be used in those facilities.. The microgravity tests will be conducted in the International Space Station, with the first flight manifested for October 2004. (Project in collaboration with Maryland University at College Park).

MEMS-based Rotary Internal Combustion Micro-Engine (DARPA/MEMS): Research aimed to develop a Micro Electronic Mechanical System (MEMS)-based rotary internal combustion micro-engine, that would be capable of delivering powers of the order of miliwats using liquid fuels. Major features of such engine would be: planar (wafer) geometry, silicon based ceramic material, high temperature semi-adiabatic cycle, normal or catalytic combustion, direct rotational torque. Because liquid fuels have a much higher power density than batteries, the project aims at the replacements of batteries in cases were weight is critical. Potential applications include propulsion of small devices and portable power generation.

Microgravity Production of Nanoparticles of Novel Materials Using Plasma Synthesis (NASA Ground Based Program): The overall objective of the research is to study the formation in reduced gravity of particulate of novel materials, in the nano-meter size, and of high quality, using plasma synthesis. Particular emphasis will be placed on non-oxide materials like SiC, SiN, c-BN, etc. The interest is to determine how microgravity synthesis can improve the quality and yield of the nanoparticles and synthesized powder. The particulate could be applied to the growth of nano-systems, such as MEMS based combustion systems, catalytic nano-reactors, fluidized bed reactors and heat exchangers, or to build nano-structures.

Carbon Monoxide and Soot Formation in Inverse Diffusion Flames (NASA Ground Based Program): The objective of the research is to experimentally and computationally study CO and soot processes in laminar, inverse diffusion flames, which is a special case of underventilated combustion. An understanding of noxious gas formation and flame soot signatures during underventilated fires in spacecraft will be obtained, a goal in line with the Human Exploration and Development of Space (HEDS) objective of achieving earlier, more sensitive fire detection systems for use in microgravity scenarios. The project has additional practical significance for predicting the composition of the intermediate products from fuel-rich zones in practical staged combustors.

Flame Characteristics of Solid Fuels in Microgravity Conditions and Very Small Flow Velocities (ESA/Spain): Collaboration with the ETSIA, Universidad Politecnica de Madrid, Spain to study the flammability limits, surface flame spread, flame characteristics and stability limits of the combustion of solid fuels in oxidizer mixtures in microgravity, low velocity flows. The project has been approved by NASA to be conducted in the International Space Station

PREVIOUS PROJECTS

Flame Spread over Solid Fuels in Opposed and Concurrent Oxidizing Flows (NIST): Research aimed to the determination of the mechanisms controlling the spread of fire in convective oxidizer flows. Includes theoretical and experimental studies of the effect of the oxidizer flow velocity, turbulence intensity, and oxygen concentration on the rates of flame

spread and steady burning, of solid combustible materials. The results are used in the development of fire models and of materials flammability tests.

Ignition and Extinction of Condensed Fuels (NSF): Research includes theoretical and experimental studies of ignition and diffusion flame extinction in boundary layer oxidizer flows established over the surface of solid and liquid fuels. The results provide fundamental information about the limiting conditions of condensed fuel burning.

Liquid Fuel Spray Ignition (ARO/TACOM): Study of the mechanisms of ignition and combustion of liquid fuel droplets and sprays under supercritical conditions. The project includes theoretical and experimental tasks. The results aim to improve the combustion efficiency and reduce emissions of diesel engines and gas turbines.

Stability of Gaseous Fuel Flames (NASA LeRC): Project to study the effect of buoyancy on the stability of premixed and diffusion flames. It includes experimental studies conducted at normal and reduced gravity in the NASA 2.2 seconds drop tower. The results are used to improve our understanding of the mechanisms controlling flame propagation and stabilization.

Flame Spread over Discontinuous Fuels in Microgravity (NASA/NEDO): Collaborative project with Tohoku University, Japan, to study the propagation of flames over discontinuous fuels in reduced gravity. The microgravity experiments are to be conducted in the JAMIC drop tower facility in Saporo, Japan

NOx reduction in Diesel Engines by Ammonia Injection (Extengine Transport Systems): Study of the feasibility and performance of adding ammonia in the exhaust manifold of diesel engines to reduce NOx emissions. The results of the project could result in the implementation of the method in stationary and moving power plants using diesel to reduce emissions.

Liquid Fuel Pool Fires and Boilover Burning of Fuels Spilled on Water (CNRS, France): Collaboration with LCD-ENSMA, University of Poitiers, France, to study the burning characteristics (boilover) of liquid fuel spills, particularly the conditions leading to the nucleate boiling of the sub-layer water and the subsequent explosive burning of heavy hydrocarbon fuels (diesel oil, heating oil, etc.) floating on the water.

High Efficiency, Low Nox, Natural Gas Burner (UERG): Feasibility study of a two stage, ultra-low Nox and CO natural gas burner. It consists of a first stage with a premixed flame anchored at a porous burner with a highly radiant surface, and a second stage with a lean turbulent diffusion flame. The burner could be developed for use in appliances and small boilers

Resonant Gas Burner (Osaka Gas, Japan): Project to study the feasibility and performance of a gas burner operating on a resonant vortex combustion mode. The large residence times and enhanced mixing of the resonant vortex operation could permit a lean operation of the burner that would be more efficient and produce less Nox emissions.

CARLOS FERNANDEZ-PELLO

Publications in Refereed Archival Journals and Conference Proceedings

1. "Surface Temperature Histories During Downward Propagation of Flames on PMMA Sheets," *Ing. Aero. & Astron.* ,**135**, 41-53, 1974 (with M. Kindelan and F.A. Williams).

2. "Laminar Flame Spread Over PMMA Surfaces," *Fifteenth Symposium (International) on Combustion*, The Combustion Institute, 217-231, 1975 (with F.A. Williams).

3. "Experimental Techniques in the Study of Laminar Flame Spread Over Solid Combustibles," *Combustion Science and Technology*, **14**, 155-167, 1976 (with F.A. Williams).

4. "A Theory of Laminar Flame Spread Over Flat Surfaces of Solid Combustibles," *Combustion and Flame*, **28**, 251-277, 1977 (with F.A. Williams).

5. "Downward Flame Spread Under the Influence of Externally Applied Thermal Radiation," *Combustion Science and Technology*, **17**, 1-9, 1977.

6. "Upward Laminar Flame Spread Under the Influence of Externally Applied Thermal Radiation," *Combustion Science and Technology*, **17**, 87-99, 1977.

7. "A Theoretical Model for the Upward Laminar Spread of Flames Over Vertical Fuel Surfaces," *Combustion and Flame*, **31**, 135-148, 1978.

8. "An Application of a Two-Component Laser Doppler Velocimeter to the Measurement of Flows Induced by Flames Propagating Over Condensed Fuels," *Applied Optics*, **17**, 23, 3843-3850, 1978 (with R.J. Santoro, F.L. Dryer, and I. Glassman).

9. ."Downward Flame Spread in an Opposed Forced Flow," *Combustion Science and Technology*, **19**, 19-30, 1978 (with S.R. Ray and I. Glassman).

10. "On the Dominant Mode of Heat Transfer in Downward Flame Spread," *Seventeenth Symposium (International) on Combustion*, The Combustion Institute, 1201-1209, 1979 (with R.J. Santoro).

11. "Initial Observations on the Free Droplet Combustion Characteristics of Water-in-Fuel Emulsions," *Combustion Science and Technology*, **21**, 1-14, 1979 (with J.C. Lasheras and F.L. Dryer).

12. "Flame Spread in a Forward Forced Flow," *Combustion and Flame*, **36**, 63-78, 1979.

13. "Laser Doppler Velocimetry as Applied to the Study of Flame Spread Over Condensed Phase Materials," *Laser Velocimetry and Particle Sizing, Proceedings of the Third International Workshop on Laser Velocimetry*, 166-170, 1979 (with R.J. Santoro, F.L. Dryer, and I. Glassman).

14. "A Study of the Heat Transfer Mechanisms in Horizontal Flame Propagation," *Journal of Heat Transfer*, **102**, 2, 357-363, 1980 (with S.R. Ray and I. Glassman).

15. "Experimental Observations on the Disruptive Combustion of Free Droplets of Multicomponent Fuels," *Combustion Science and Technology*, **22**, 195-209, 1980 (with J.C. Lasheras and F.L. Dryer).

16. "Flame Spread in an Opposed Forced Flow: The Effect of Ambient Oxygen Concentration," *Eighteenth Symposium (International) on Combustion*, The Combustion Institute, 579-589, 1980 (with S.R. Ray and I. Glassman).

17. "On the Disruptive Burning of Free Droplets of Alcohol/n-Paraffin Solutions and Emulsions," *Eighteenth Symposium (International) on Combustion*, The Combustion Institute, 293-305, 1980 (with J.C. Lasheras and F.L. Dryer).

18. "A Unified Analysis of Concurrent Modes of Flame Spread," *Combustion Science and Technology*, **26**, 147-156, 1981 (with C.P. Mao).

19. "Fluid Mechanical Structure of a Premixed Flame in a Flat Plate Boundary Layer Flow," *Proceedings of the First Specialists Meeting (International) of the Combustion Institute*, University of Bourdeaux, France, Vol. I, 249-254, 1981 (with C. Trevino).

20. "Catalytic Flat Plate Boundary Layer Ignition," *Combustion Science and Technology*, **26**, 245-253, 1981 (with C. Trevino).

21. "Influencia de la Localizacion de una Zona de Alta Temperatura de una Placa Plana sobre el Proceso de Ignicion de Gases Premezclados," *Proceedings of the VII Congreso de la Academia Nacional de Ingenieria de Mexico*, 228-232, 1981 (with C. Trevino).

22. "A Theory for the Free-Convective Burning of a Condensed Fuel Particle," *Combustion and Flame*, **44**, 97-112, 1982 (with C.K. Law).

23. "A Unified Criterion for the Convective Extinction of Fuel Particles," *Combustion and Flame*, **44**, 113-124, 1982 (with X. Wu and C.K. Law).

24. "An Analysis of the Forced Convective Burning of a Combustible Particle," *Combustion Science and Technology*, **28**, 305-314, 1982.

25. "Controlling Mechanisms of Flame Spread," Published jointly in *Fire Science and Technology (Japan)* **2**, 1, 17-54, 1982 and *Combustion Science and Technology*, **32**, 1-31, 1983 (with T. Hirano).

26. "On the Mixed-Convective Flame Structure in the Stagnation Point of a Fuel Particle," *Nineteenth Symposium (International) on Combustion*, The Combustion Institute, 1037-1044, 1982 (with C.K. Law).

27. "On the Influence of the Plate Thickness on the Boundary Layer Ignition for Large Activation Energies," *Combustion and Flame*, **49**, 91-100, 1983 (with C. Trevino).

28. "Mixed Convective Burning of a Vertical Fuel Surface," *Proceedings of the 1983 ASME-JSME Thermal Engineering Joint Conference*, **4**, 295-301, 1983 (with P.J. Pagni).

29. "Theory of the Mixed Convective Combustion of a Spherical Fuel Particle," *Combustion and Flame*, **53**, 23-32, 1983.

30. "An Investigation of Steady-Wall Ceiling and Partial Enclosure Fires," *Journal of Heat Transfer*, **106**, 1, 221-228, 1984 (with C.P. Mao and J.A.C. Humphrey).

31. "Mixed Convective Burning of a Fuel Surface with Arbitrary Inclination," *Journal of Heat Transfer*, **106**, 2, 304-309, 1984 (with C.P. Mao and P.J. Pagni).

32. "Flame Spread Modeling," *Combustion and Flame*, **30,** 119-135, 1984.

33. "Aerodynamics of Premixed Flames in Flat Plate Boundary Layers," *Combustion Science and Technology*, **38**, 293-313, 1984 (with C. Trevino).

34. "Convective Structure of a Diffusion Flame Over a Flat Combustible Surface," *Combustion and Flame*, **57**, 209-236, 1984 (with C.P. Mao and H. Kodama).

35. "Mixed Convective Droplet Combustion with Internal Circulation," *Combustion Science and Technology*, **42**, 47-66, 1984 (with R.H. Rangel).

36. "A Study of the Controlling Mechanisms of Flow Assisted Flame Spread," *Twentieth Symposium (International) on Combustion*, The Combustion Institute, 1575-1582, 1984 (with H.T. Loh).

37. "Gas Phase Ignition of a Solid Combustible in a Convective Flow," *Latinamerican Journal of Heat and Mass Transfer*, **9**, 131-147, 1985 (with C. Trevino).

38. "Predictions of Flame Spread Hydrodynamics over Liquid Fuels," *Physical Chemical Hydrodynamics* **6**, No. 4, 347-372, 1985 (with M. Furuta and J.A.C. Humphrey).

39. "Flow Assisted Flame Spread Over Thermally Thin Fuels," *Proceedings First International Symposium on Fire Safety Science*, Hemisphere Publishing Co., Washington, D.C., 65-74, 1985 (with H.T. Loh).

40. "Droplet Ignition in Free Convection," *Progress in Astronautics and Aeronautics, Vol. 105, Dynamics of Reactive Systems, Part II* , 239-252, 1985 (with R. Rangel).

41. "An Analysis of Gas Phase Ignition by Catalytic and Non-Catalytic Cylindrical Surfaces," *Combustion Science and Technology*, **48**, 45-54, 1986, (with R. Rangel and C. Trevino).

42. "Buoyancy Effects on Smoldering Combustion," *Acta Astronautica*, **13**, 689-696, 1987 (with S. Dosanjh and P.J. Pagni).

43. "Forced Concurrent Smoldering Combustion," *Combustion and Flame*, **68**, 131-142, 1987 (with S. Dosanjh and P.J. Pagni).

44. "Extinction and Stabilization of a Diffusion Flame on a Flat Combustible Surface with Emphasis on Thermal Controlling Mechanisms," *Combustion Science and Technology*, **44**, 1-6, 37-50, 1987 (with H. Kodama and K. Miyasaka).

45. "An Analysis of the Ignition by Vapor Absorption of Radiation of a Vaporizing Fuel at Zero-Gravity," *Progress in Astronautics and Aeronautics*, **113**, 115-127, 1988 (with B. Amos).

46. "Mixed-Convective Film Boiling Around a Cylinder," *Latin American Applied Research*, **18**, 131-137, 1988 (with R. Rangel and C. Trevino).

47. "Model of the Ignition and Flame Development on a Vaporizing Combustible Surface in a Stagnation Point Flow: Ignition by Vapor Fuel Radiation Absorption," *Combustion Science and Technology*, **62**, 331-343, 1988 (with B. Amos).

48. "Model of the Flow Assisted Spread of Flames over a Thin Charring Combustible," *Twenty-Second International Symposium on Combustion*, The Combustion Institute, 1205-1212, 1988 (with C. DiBlasi, S. Crescitelli, and G. Russo).

49. "On the Flame Structure at the Base of a Pool Fire," *Twenty-Second International Symposium on Combustion*, The Combustion Institute, 1291-1298, 1988 (with A. Bouhafid, J.P. Vantelon and P. Joulain).

50. "On the Influence of the Gas Velocity Profile on the Theoretically Predicted Opposed Flow Flame Spread," *Combustion Science and Technology*, **64**, 289, 1989 (with C. DiBlasi, S. Crescitelli, and G. Russo).

51. "Prediction of the Dependence on the Opposed Flow Characteristics of the Flame Spread Rate Over Thick Solid Fuels," *Second International Symposium on Fire Safety Science*, 119-128, 1989 (with C. DiBlasi, S. Crescitelli and G. Russo).

52. "Experimental Observations of the Effect of Buoyancy on Co-Current Smoldering," *Journal of Fire and Materials,* **14**, 145, 1989 (with J. Newhall and P.J. Pagni).

53. "Flame Spread in an Opposed Turbulent Flow," *Combustion and Flame*, **81**, 1, 40-49, 1990 (with L. Zhou and R. Cheng).

54. "A Mixing and Deformation Mechanism for a Supercritical Fuel Droplet," *Combustion and Flame*, **81**, 1, 50-58, 1990 (with H.S. Lee, G. Corcos, and A.K. Oppenheim).

55. "Gravitational Effects on Cellular Flame Structure," *Twenty-Third International Symposium on Combustion,* The Combustion Institute, 1657, 1990, (with C. Dunsky).

56. "Concurrent Turbulent Flame Spread," *Twenty-Third International Symposium on Combustion*, The Combustion Institute, 1709, 1990, (with L. Zhou).

57. "Turbulent Burning of a Flat Fuel Surface," *Proceedings Third International Symposium on Fire Safety Science*, Elsevier Applied Science, 415, 1991 (with L. Zhou).

58. "A Study of the Fire Performance of Electrical Cables," *Proceedings Third International Symposium on Fire Safety Science*, Elsevier Applied Science, 237, 1991 (with H. Hasegawa, K. Staggs, A. Lipska-Quinn, and N. Alvares).

59. "Influence of an External Radiant Flux on a Moderate Scale Pool Fire," *Combustion and Flame*, **86**, 237, 1991 (with X. Zhang, J.P. Vantelon and P. Joulain).

60. "Pool and Wall Fires: Some Fundamental Aspects," *Proceedings of the ASME/JSME Thermal Engineering Joint Conference*, **5**, 261, 1991.

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